

ANALYSIS AND IMPROVING THE OPERATIONS FROM A MANUFACTURING CELL USING THE DISCRETE EVENT SIMULATION

Ayash MOUSSA¹

The purpose of this paper is to describe, analyse and optimize the working sequences from a manufacturing cell of the hydraulic pumps components, using a simulation model with graphic representation of the processes and the relationship between them. The objective of the simulation is to establish the system performance, the resource usage, the batch size and the bottlenecks. For the development of the simulation model we used the tools provided by the dedicated software Delmia Quest, the results allowing to evaluate and improve the performance of the system by changing the layout and optimizing the resource usage.

Keywords: Discrete Event Simulation, facility layout, manufacturing cell, Delmia Quest

1. Introduction

In the design, implementation and operation of systems, modeling and simulation has an important role, in the context of the rapid development of manufacturing systems, which are becoming more flexible and must provide the ability to react in a fast way to continuous changes [1]. The simulation can provide the necessary tools for evaluate the systems performances, for solving the problems and to meet the new challenges.

The discrete event simulation, where the events occur instantaneous and appear only at certain point in time, is one of the most suitable technologies for decision evaluation in the designing and simulating of the processes. This type of simulations can be used in various areas, such as logistics, telecommunications network, manufacturing systems etc. In this paper we present the simulation of a manufacturing process of a pump component through using a dedicated software, Delmia Quest. The reports will provide useful information for finding a practical method of process optimization through the identification of bottlenecks, the resources usage and the optimal batch size. For designing the production system simulation model it is necessary to pick the routes of the entities from the manufacturing cell, to correspond to the manufactured and half manufactured parts and to choose the machines and resources, using the simulation making it possible to estimate the total investment, the production costs and productivity of

¹ Eng., Dept. of Machine Tools and Production Systems, University POLITEHNICA of Bucharest, Romania, e-mail: abusiefayash@hotmail.com

the system. With the help of the simulation a comparison between two or more systems can be achieved.

The Quest software offers a unique collaborative environment for the process engineers, alongside with the production and using of the human resources, for developing and ensuring the best practice of the material flow, during the design of the manufacturing processes. With the help of Quest, virtual plants can be created, both in the 2D and 3D graphics environment. Quest provides, through its internal library, a very large list of predefined elements, such as machines, parts, labor, buffers, sources, that allow the users to create in a fast way a simulation model. The users can design different layouts for machines, the manufacturing flow, the staff schedule, and can incorporate ergonomics constraints. The results can be displayed as charts and diagrams. The results can also be extracted from the model and send to different files type for analysis, such as Microsoft Excel®.

2. Manufacturing systems simulation

About simulation

The simulation is to representation of the real life processes or of the systems, in time [4]. The simulation needs the development of a model which contains all the key characteristics or the behaviour/ functions of the physical or abstract system, or the process. The model represents the actual system, and the simulation give us the functionality of the system through time.

Simulation can be used to highlights the effects of the alternative conditions and the course of the actions. It is also used for the real systems that can't be accessed, because either they are not available, either accessing them is dangerous and inaccessible, or it is in the phase of the development, before the actual construction, or simply does not exist [5].

The key aspects of the simulation cover information on the relevant behaviour and characteristics from a valid source, the use of simplifying approximations and assumptions as well as fidelity and validity of the simulation.

It has a very large variety of applications but the present study aimed to realise a simulation model for a manufacturing system. The simulation, is used especially to examine the effects of the investments or improvements in the manufacturing system and for evaluating the performances like the fabrication line, warehouse activities and distribution centres.

The performances of the systems can be evaluated by following the next parameters:

- Cycle time (how long it take to produce one part) ;
- Utilization of resource, labour, and machines;
- Bottlenecks and choke points;

- Queuing and the optimal batch size ;
- Queuing and delays caused by material-handling devices and systems;
- Effectiveness of scheduling systems;
- Effectiveness of control system

The examination of the manufacturing system performances examination is made by the generating of static reports for the process development times and for transport operations. For complex activities the Discrete Events Simulation will be used because of its ability to consider the dynamic changes in the systems. A production system is often dynamic, depending on variations in manufacturing processes as the necessary time for assembly operations, settings times of machines, breaks, errors and stops.

The discrete event simulation designs the system functionality like a succession of discrete events in time. Every event occurs at a defined moment in time and it indicates a state change in the system. [6]

It is assumed that between two consecutive actions, there are no changes at the system level, therefore the simulation can pass from one action to another.

In these days, on the market, there is a variety of dedicated softwares for discrete events simulation. They differ as a mode of use and applicability but share the same foundation.

Manufacturing structures – manufacturing cell

The manufacturing cell is one of the most important component of a production system. It can meet market demand for a wide range of products and can manufacture products in a limited or small series and also can adapt quickly to the market changes, thereby improving its flexibility. The manufacturing cell is defined as a group of machines organized by the parts or products made in a production environment. This system is used in the cell fabrication concept, which is separate from the traditional systems in which the same type of machines are united. Using the manufacturing cell improves the material flow and it suits, especially in the case of batch production and also for small size production series [1].

The product is shifted from a cell to another and each station completes the production process. The most common used machines in a manufacturing cell include lathes, milling machines, drill presses, etc. Many times the machines are aligned in “U” shape, because this allows supervisors to watch the whole process easier and to move between machines faster.

Software systems for Discrete Events Simulations

For designing and optimizing the manufacturing systems we can use simulation software that can provide reports for monitoring the performance. On

the market there is a great variety of dedicated discrete events simulation softwares suitable for analysing manufacturing systems.

Delmia Quest

Delmia Quest V5 is the software used for modelling and simulating the manufacturing cell for the hydraulic pump and it is detailed in chapter 3. For developing a Quest model we needed to follow three main steps. The first step corresponds to the selection of the virtual models for the involved resources, such as manufacturing equipments, conveying and transfer systems and labor, similar with the real production line if possible. The program provides a library with three dimensional resources – manufacturing machines(milling, lathe, drilling machines) buffers, storages systems, feeding stations, AGV systems, cranes, conveyors, AS-RS systems, labor etc. Another characteristic of this software is that the geometric models from CAD systems can be imported into the workspace. The virtual models of the resources should be placed according to the manufacturing layout. The second step consist of the defining the behaviour of the objects, technological processes and the rules of the operating systems. The object behaviour is referring to the loading, processing and unloading the parts, based on the system equipments. The logical sequences of the work operations is defined by the technological process of manufacturing, making from independent devices an entire unique logical process [9], [10]. The operating rules of the system can ensure the normal functionality of the system, avoiding the conflicts.

The third step consist of simulating the production line based on the developed model, obtaining the reports regarding the maximum batch size, performances of the system and the effectiveness of the machines and labor. Also, through the obtained results the bottlenecks can be identified and the cell layout can be improved.

3. The manufacturing cell for pump components

Cell structure

The main priority of the manufacturing companies is the production time, and each company aims to minimize the production time as much as possible in order to deliver the products on time to their customers .[11] Setting times for the machines, the time required to manufacture, materials handling times and waiting times can be optimized to improve the work processes. After making a detailed analysis of the production line for hydraulic pumps it was found that the time required to achieve product can not be optimized due to the use of machines and systems with high performances.

However, after the analysis performed by simulation the percentage of resource utilization, the effectiveness of the resources and the bottlenecks

probability of appearance was identified thereby realizing an improvement of the layout.

The hydraulic pump is composed from the components specified in the table 1.

Table 1

Hydraulic pump components

No.	Name	Quantity
1	Cover	1
2	Sealing ring or the shell	1
3	Gear	2
4	Shell	1
5	Sealing ring	1
6	Shaft	2
7	Hexagonal screw 3x8	10
8	Bush	4

In table 1 are presented the components necessary for only one type of the pump. In reality, the line provides a great variety of different capacities pumps, depending on customer specifications.

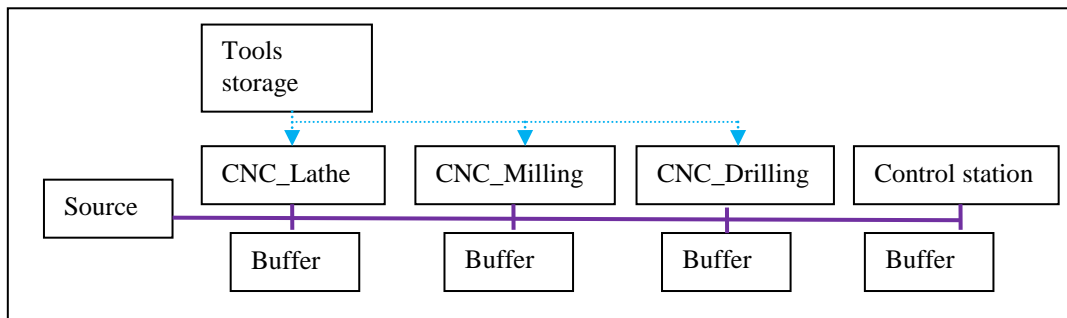
The simulation model will be designed for the manufacturing cell of the cover. The technology of manufacturing the cover consists of the operations specified in the table 2.

Table 2

The technology process of the cover component

No. Op.	Part name	Process	Machine
1	Cover	Lathe	CNC_Lathe
		Milling	CNC_Milling
		Drilling	CNC_Drilling
		Inspection	Control table

The manufacturing cell layout is presented in the figure 1. As can be observed the cell has 3 machines, a control post, a source, 3 buffers, that are placed in line. Each machine and also the control station has a corresponding human operator, that loads the raw part in the machine, unloads the parts and monitors the working process.



4. Simulation model:

In figure 2 we represented the manufacturing cell simulation model, described in the previous chapter. The simulation corresponds to a working schedule of nine hours, in which eight hours of effective work and an hour of break. The simulation model is composed form the next components:

- Source – which corresponds to the storage of the raw materials;
- Fours buffers;
- A lathe machine;
- A milling machine;
- A drilling machine;
- A control station;
- Four labor.

The cell layout of the location of the cell machinery, utilities, workspaces for employees, storage areas for raw materials, and the flow of materials and human resources in the system. There are three types of common layouts: on a single line, on two lines and loop layout. The manufacturing layout on a single line has three forms: in line, in „U” shape and semi-circular.[17].

The relation between the elements is presented in figure 3. The raw materials are transferred from the source to buffer 1, by the labor OP_STRUNJIRE_1. The labor OP_strunjire is responsible of loading, unloading and monitoring the lathe process made by machine STRUNJIRE_1. The processed part will be then transffered to buffer 2, where it will be taken over by the labor OP_FREZARE_1, which corresponds to the milling machine FREZARE_1. After the miling process is finished the part is transferred to the buffer 3. The labor OP_GĂURIRE_1 will load the parts in the drilling machine GĂURIRE_1. The last operation from the process is the control which is made by the labor OP_CONTROL_1 on the control station CONTROL_1. Here the parts can be approved or rejected. The manufacturing line has a rejection rate of 2%. The approved parts ar transffered to the buffer 4.

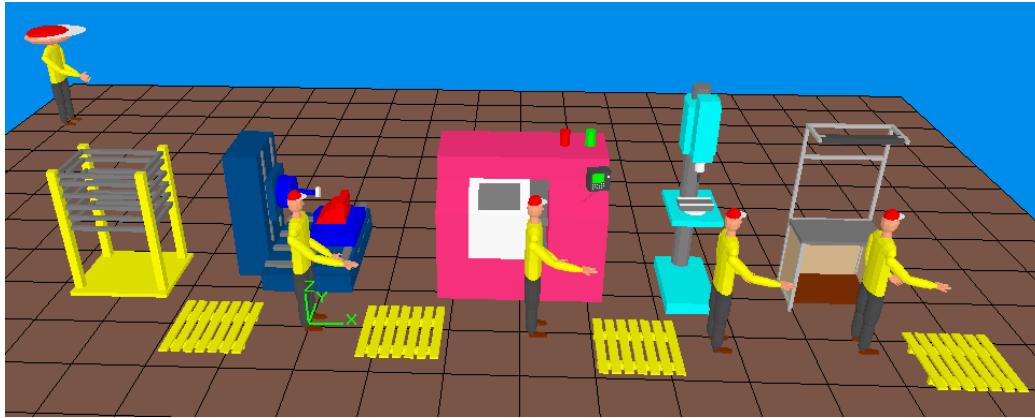


Fig.2: Simulation model in line

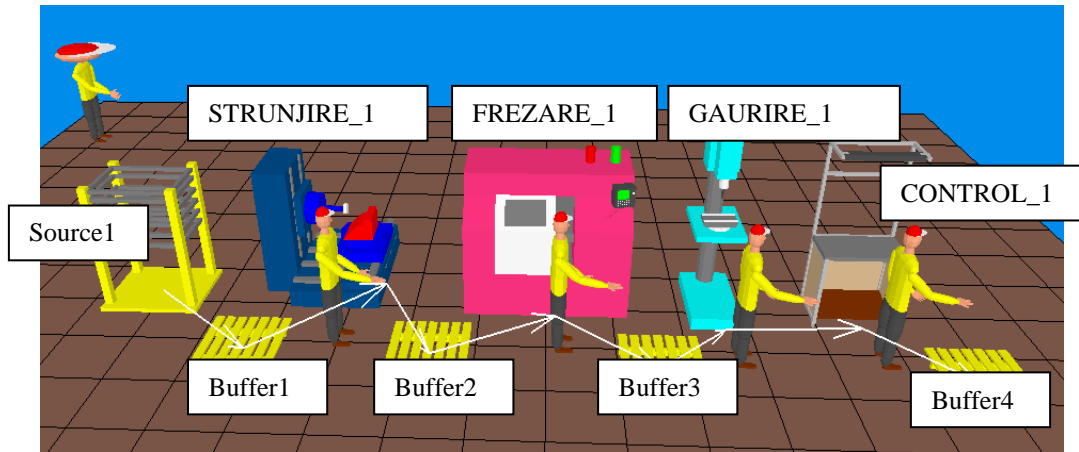


Fig.3: Elements relations

The process times for each operation are specified on the table 3.

Table 3

Process times		
Operation	Operation name	Cice time (s)
Lathe	STRUNJIRE_1	110
Milling	FREZARE_1	94
Drilling	GAURIRE_1	100
Insepection	CONTROL_1	5

Batch size

After a complete simulation (finishing the working time of nine hours) the number of finite parts obtained was 232, although the number of processed parts was 237, which means a number of 5 rejected parts.

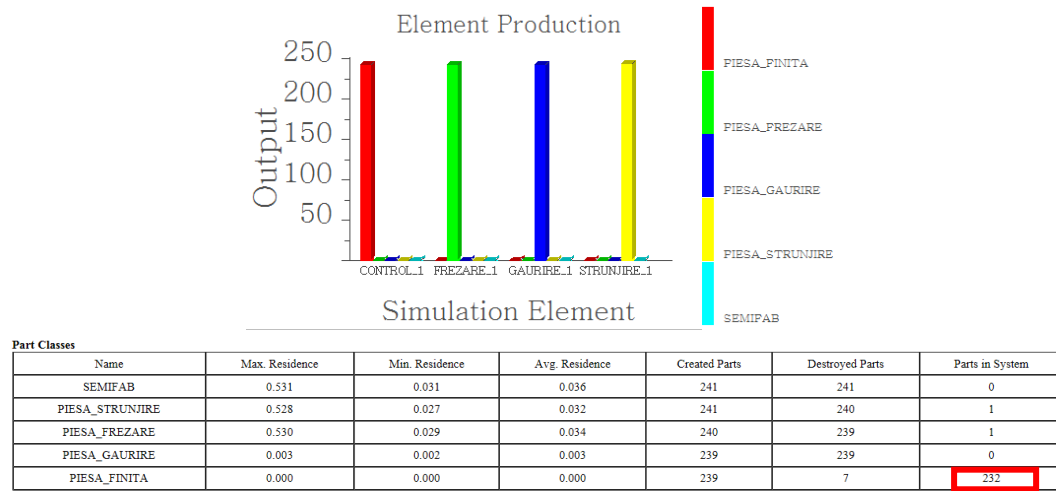


Fig.4: Parts processed

Resource usage

For the manufacturing cell resources it is necessary to establish the utilization rate. A low utilization rate means that there are waiting times that can be eliminated or improved. A high utilization of the resources means that they are overloaded and bottlenecks will appear. In figure 5 we have displayed the resources usage. It can be noted that the working process that corresponds to the manufacturing operations has a high utilization rate – 70% for the milling process, but the usage of the inspection process is very low – only 3,6% on the control station.

Name	State Times				Utilization (%)	Avg. Process Time	Parts Added	Parts Rejected	No. of Products	Avg. Cycle Time	Avg. Reqmt Time	Production Rate	Avg. Part Residence Time	Final Content
	Idle	Busy - Processing	Blocked - Unload Block	Unavailable - Shift Break										
STRUNJIRE_1	0.389	7.364	0.248	1.000	81.821	0.032	241	0	241	0.031	0.002	26.778	0.018	0
FREZARE_1	1.502	6.267	0.231	1.000	69.637	0.032	241	0	240	0.026	0.006	26.667	0.016	1
GAURIRE_1	1.216	6.645	0.139	1.000	73.832	0.033	240	0	239	0.028	0.005	26.556	0.016	1
CONTROL_1	7.519	0.332	0.149	1.000	3.688	0.033	239	7	239	0.001	0.031	26.556	0.001	0

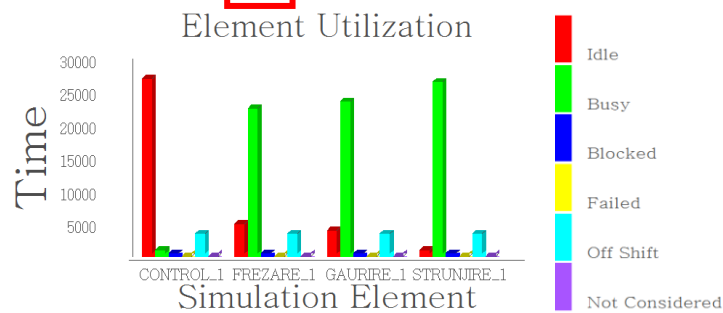


Fig.5: Resource usage

However, analyzing the workload of the labor it appears that there is a very low load factor. Working capacity of human operators is not used efficiently, therefore work processes will be improved by eliminating two human operators and reconfiguration of the cell into "U" shaped.

Name	State Times					Utilization (%)	Avg. Part Residence Time	No. of Parts Added	Avg. Contents	Distance Travelled	Final Content
	Idle	Idle - Parked	Busy - Loaded Travel	Busy - Empty Travel	Unavailable - Shift Break						
OP_STRUNJIRE_1	0.031	7.472	0.250	0.248	1.000	5.531	0.001	482	0.028	1092335.375	0
OP_FREZARE_1	0.058	7.479	0.232	0.231	1.000	5.148	0.000	480	0.026	1016766.313	0
OP_GAURIRE_1	0.086	7.634	0.140	0.139	1.000	3.102	0.001	239	0.016	612770.500	0
OP_CONTROL_1	0.088	7.613	0.149	0.149	1.000	3.314	0.001	232	0.017	654468.688	0

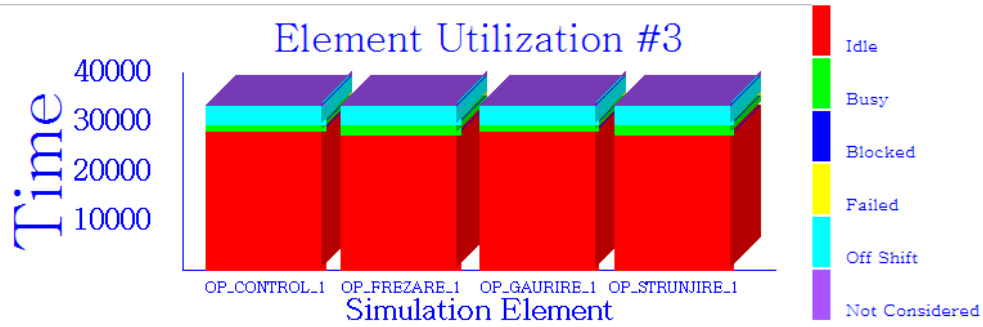


Fig.6: Labor usage

„U” shape layout

Reducing the number of labor from 4 to 2 it is observed that the efficiency of work processes is increased by more than 50%, keeping the same process parameters. After the configuration of the cell changed the same number of finite parts is obtained, for the same work schedule with 8 hour of effective work – 237 .

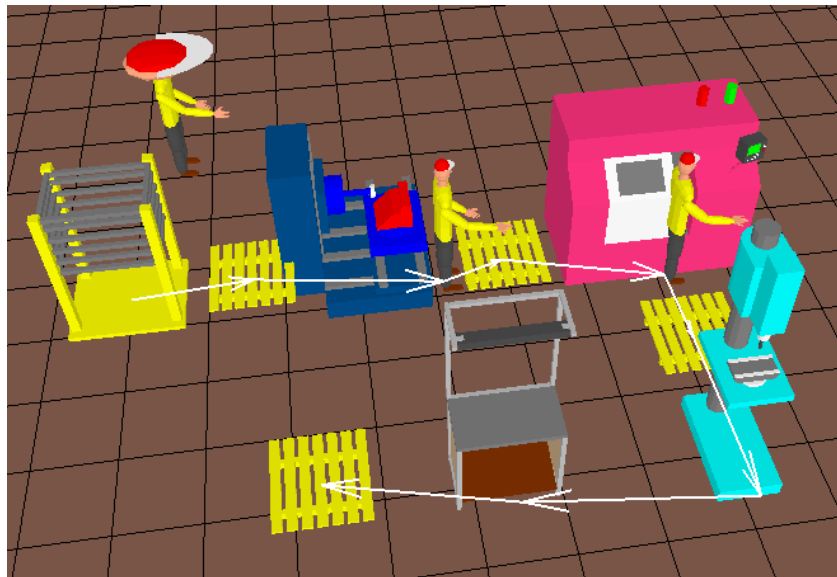


Fig.7: Improved layout U- shape

Labor

Name	State Times						Utilization (%)	Avg. Part Residence Time	No. of Parts Added	Avg. Contents	Distance Travelled	Final Content
	Idle	Idle - Parked	Busy - Loaded Travel	Busy - Empty Travel	Blocked - Unload Block	Unavailable - Shift Break						
OP_STRUNJIRE_1	0.031	6.728	0.534	0.708	0.000	1.000	13.797	0.001	721	0.059	2724973.000	0
OP_FREZARE_1	0.058	6.331	0.527	0.835	0.250	1.000	15.124	0.001	712	0.086	2987198.500	1

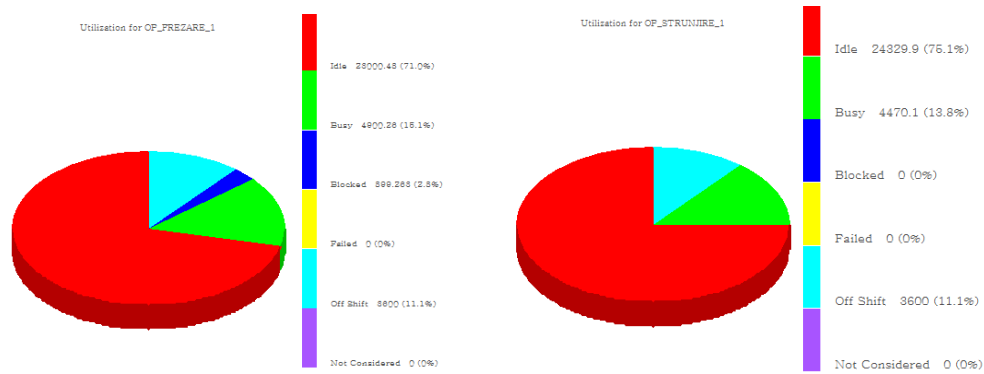


Fig.8: Utilization rate for the labor

In the chart from the figure 9 it is represented the labor efficiency from the two compared models – in line and U- shape.

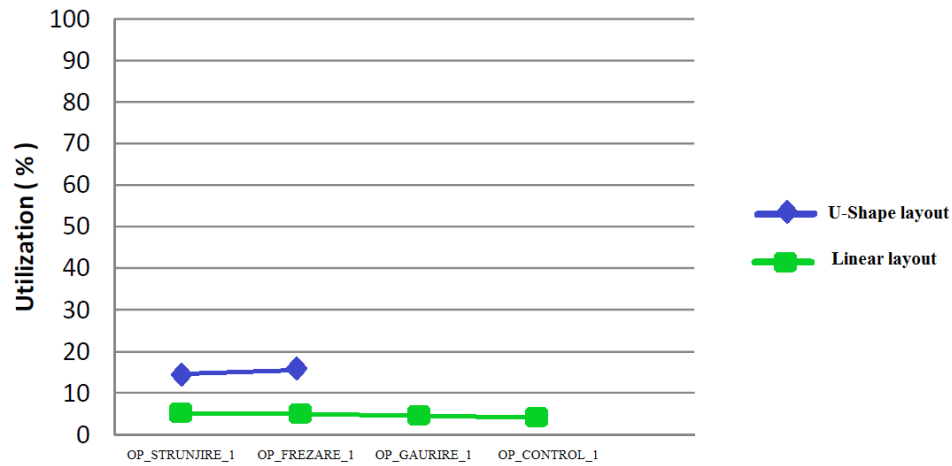


Fig.9: Human resource efficiency in the two models

Bottlenecks identification

The bottlenecks occurs in the resource level and has the greatest influence on the system performance.

In our simulation the bottlenecks are:

- Machines with waiting times – idle in the manufacturing process;
- Overloaded resources;

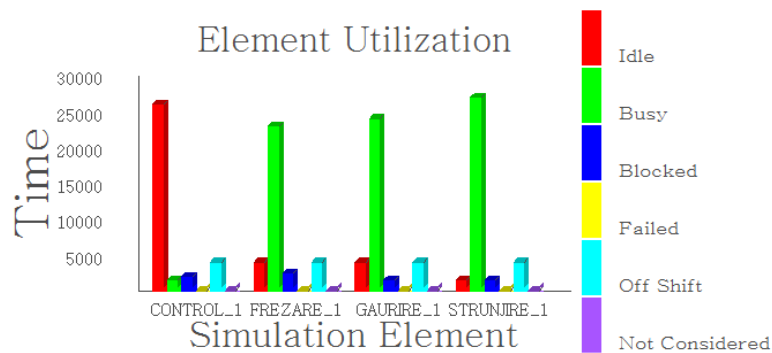


Fig.10: Resource usage in time

5. Conclusions

Using process simulation softwares can significantly reduce costs, improve productivity and efficiency, help to plan and explain the facilities layouts using a graphical interface easy to use.

The purpose of this study was to analyse and improve the working processes from a manufacturing cell of pump components, using the Discrete Events Simulation software – Delmia Quest. Through the simulation we were able to determine the batch size, the efficiency of the resources, the bottlenecks, the system behavior and productivity under the layout changes made for a working schedule of 9 hours.

Initially we developed a simulation model in which devices are placed linearly. Each unit has a correspondent human resource, the cell contains a total of four machines resources and four labor resources.

After the simulation was complete the reports were analyzed and it was concluded that the labor resources have a very low efficiency. Following these results, the layout of the machinery within the cell has changed, and the labor resources has been reduced to two. The new layout of the machines is the "U" shape.

Resource performance increased from an average of 4.2% to 14.5% for the same number of processed parts – 237.

REFERENCES

- [1]. *Elena-Iuliana Gingu (Boteanu)*, Improving layout and workload of manufacturing system using Delmia Quest simulation and inventory approach, International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Volume 1 Issue 6 (Iulie2014).
- [2]. FlexSim online company history website .
- [3]. *Garrido, Joés M. (2009)*. Object Oriented Simulation. Springer. ISBN 978-1-4419-0515-4.

- [4]. *J. Banks; J. Carson; B. Nelson; D. Nicol* (2001). Discrete-Event System Simulation. Prentice Hall. p. 3. ISBN 0-13-088702-1.
- [5]. *Sokolowski, J.A.; Banks, C.M.* (2009). Principles of Modeling and Simulation. Hoboken, NJ: Wiley. p. 6. ISBN 978-0-470-28943-3.
- [6]. *Stewart Robinson* (2004). Simulation – The practice of model development and use. Wiley.
- [7]. *Yanyan Zhang, Cheng Su, Yong Shang and Zhongxue Li*, Service Rate Optimization of Manufacturing Cell Based on Cost Model, Advanced Materials Research Vols. 314-316 (2011) pp 2055-205, Online available since 2011/Aug/16 at www.scientific.net.
- [8]. <http://www.3ds.com/products-services/delmia/>.
- [9]. *Kendal K., Mangin C.* et.al, Applied Science and Manufacturing, Vol. 7(1998),p.711 -720
- [10]. *Kingstam P, Cullander P*, Computers in Industry, Vol. 38(5) (1999),p.173 -186.
- [11]. *J.J.Kathiriya, V.D.Amareliya ,S.H.Kapadiya*, Production process analysis on manufacturing of hydraulic gear pump, Mechanical Engineering: An International Journal (MEIJ), Vol. 1, No. 1, May 2014.
- [12]. *E.Kalisz* - PCREPORT, Simularea sistemelor, octombrie 1996.
- [13]. Delmia/Quest User Manual, Chapter 1.6. Delmia/Quest 2006.